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IS : 2597 (Part I) - 1964

Indian Standard

CODE OF PRACTICE FOR THE USE OF ELECTRONIC VALVES

PART I COMMERCIAL RECEIVING VALVES

(First Reprint OCTOBER 1981)

UDC 621.385

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Price Rs 10·00

March 1964

Indian Standard

CODE OF PRACTICE FOR THE USE OF ELECTRONIC VALVES

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AMENDMENT NO. 1 JULY 1973

TO

IS : 2597 (Part I)-1964 CODE OF PRACTICE FOR THE USE OF ELECTRONIC VALVES

PART I COMMERCIAL RECEIVING VALVES

Alterations

(*First cover page, pages* 1 *and* 3, *Title*) — Substitute the following for the existing title:

' *Indian Standard*

CODE OF PRACTICE
FOR THE USE OF ELECTRON TUBES

PART I COMMERCIAL RECEIVING TUBES '

Substitute ' electron tubes ' *for* ' electronic valves ' and ' electron tubes and valves ' wherever it appears in the standard.

Substitute ' tube ' *for* ' valves ' wherever it appears in the standard.

(ETDC 39)

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Indian Standard

CODE OF PRACTICE FOR THE USE OF ELECTRONIC VALVES

PART I COMMERCIAL RECEIVING VALVES

0. FOREWORD

0.1 This Indian Standard (Part I) was adopted by the Indian Standards Institution on 3 February 1964, after the draft finalized by the Electronic Components Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 With the establishment of electronic valve manufacture in India, the need has been felt for bringing out the necessary national standards on the subject. A start has been made in this direction on the subject of receiver valves which are currently under production. It is proposed to bring out a series of Indian Standards covering tubes and valves and this code is one of that series. The other standards will cover methods of measurements of characteristics, standard outlines and terminology, etc.

0.3 This code is intended to give general guidance to the designers of electronic equipment to be supplemented by data sheets from the valve manufacturer so that optimum efficiency, performance and life can be obtained. This part covers the recommendations applicable to commercial receiving valves. Further parts covering other types of valves, such as transmitting valves, industrial valves and special quality valves, will be published shortly.

0.4 The recommendations made in this code relate to normal commercial application of valves and in cases where a higher degree of reliability is called for, for example, in certain professional equipment, additional precautions will have to be taken and for this, reference should be made to manufacturers' catalogues.

0.5 This code is based, to a large extent, on B.S. CP 1005 : 1962 The Use of Electronic Valves, issued by the British Standards Institution. The rating systems (*see* 3.3.2) have been aligned with IEC Publication 134-1961 Rating Systems for Electronic Tubes and Valves and Analogous Semiconductor Devices, issued by the International Electrotechnical Commission (IEC).

0.6 A limited terminology for the immediate purposes of this code has been included in this standard. A complete terminology on electronic valves is separately under preparation.

0.7 Explanatory paragraphs in italics have been added under most of the recommendations in this code.

0.8 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960 Rules for Rounding Off Numerical Values (*Revised*). The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

0.9 This code is intended chiefly to lay down recommendations for the use of commercial receiving valves, and it does not include all the necessary provisions of a contract.

1. SCOPE

1.1 This standard (Part I) covers recommendations for use of commercial receiving valves.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Bogey Electronic Devices — An electronic device whose characteristics have the published nominal values for the type. A bogey electronic device for any particular application can be obtained by considering only those characteristics which are directly related to the application.

2.2 Cathode Interface Impedance — An electrical impedance existing between the cathode base metal and the cathode coating.

2.3 Contact Potential Difference — The difference between the work functions of two materials, divided by the electronic charge.

2.4 Electrode Current — The net current from an electrode into the interelectrode space. The terms cathode current, anode current, grid current, and so on, are used to designate electrode currents from these specific electrodes.

2.5 Electrode Potential — Refers to the potential (or voltage) with reference to the cathode or negative filament connection unless otherwise specified.

2.6 Electron Device — A device in which conduction is principally by electrons moving through a vacuum, gas or semiconductor.

2.7 Electronic Valve — Valve, vacuum tube, or photocell in which conduction takes place by electrons moving through a vacuum or gaseous medium within a gas-tight envelope. The term ' valve ' is used for convenience throughout the code and is to be read as meaning ' electronic valve '.

2.8 Rating — A value which establishes either a limiting capability or a limiting condition for an electronic device. It is determined for specified values of environment and operation, and may be stated in any suitable terms.

NOTE — Limiting conditions may be either maximum or minimum.

2.9 Rating System — The set of principles upon which ratings are established and which determine their interpretation.

NOTE — The rating system indicates the division of responsibility between the device manufacturer and the circuit designer, with the object of ensuring that the working conditions do not exceed the ratings.

3. RECOMMENDATIONS

3.1 Published Data — The published data on specific valve types should always be carefully studied before the design of an equipment is undertaken. Where exceptional need arises or where a valve is to be used in an application which does not appear to be provided for by the published data, the valve manufacturer should be consulted so that the equipment designer may have additional information from the manufacturer for the application. New application of a valve may need suitable tests to be provided during manufacturing. Hence equipment designer should keep the valve manufacturer informed with the current trend of requirements.

Published ratings represent the valve manufacturer's opinion of the most satisfactory compromise between high efficiency and long life, and are based upon a thorough study of valve performance either to normal practice or to the manufacturer's forecast of future practice. This is of particular importance when major departures from current practice are contemplated; the valve manufacturer should be informed well in advance, so that, if necessary, new ratings can be established from preliminary trials and confirmed by further tests from regular production batches. Unless the valve manufacturer is so informed, he will be faced with the choice of suggesting either a rating which is unnecessarily conservative or one involving unknown risks.

3.1.1 *Selection of Electronic Valves* — It is generally not desirable for valves to be specially selected for individual equipment. As it is difficult to estimate the effect of valves with one or more characteristics at the limiting value, it is very desirable that initial tests be made with the largest reasonable number of equipments and valves from regular production.

3.1.2 *Early Samples* — When equipment is being designed on the basis of new valve types, it should be borne in mind that there may be considerable variations in characteristics and dimensions between first samples and subsequent production.

Early samples of new valve types embody a considerable amount of handwork and are not necessarily typical of mass-produced article. Hand-made samples may be superior in some respects, but in general vary from valve to valve. Valves manufactured in regular production would, in general, be more consistent than those made in a laboratory. Circuit design based on the mean characteristics of a limited number of early sample valves is liable to serious error and should not be adopted for production.

3.2 Dimensions — Particular attention should be paid to the published dimensions when using established types in the design of equipment. Dimensions should not be taken from individual valves to ensure that adequate space is allowed for valve shield, and retaining and mounting devices for all valves of the type.

3.3 Ratings

3.3.1 *General*

a) Ratings are the set of limiting values defining the operating conditions within which the valve can be expected to give satisfactory performance. These are so chosen that failure rate, life and performance are sufficiently satisfactory. The expectation of life generally decreases continuously as the ratings are approached. Exceeding the rating accelerates the decline. Barring a few exceptions the more conservative the use of the valve with respect to ratings the greater is the life expectancy and reliability.

b) The first maximum or minimum rating reached should be the limiting factor. All ratings are not mutually compensating, for example, it is not safe to assume that one rating (say, maximum anode voltage) may be exceeded provided a corresponding reduction is made in some other rating (for example, anode current), although this may be permissible in some instances. Further, a rating variation authorized for a particular valve type is not necessarily applicable to another similar type. Use of valves in applications where the absolute maximum ratings are exceeded should be done only in consultation with the valve manufacturer.

3.3.2 *Rating Systems*

3.3.2.1 *General* — Rating systems are so chosen by the device manufacturer to provide acceptable serviceability of the *device*, taking responsibility for the effect of changes in operating conditions due to variations in the characteristics of electronic device under consideration. The designer should design the equipment so that, initially and throughout life, no design maximum value for the intended source is exceeded with a bogey device under the worst probable operating conditions with respect to supply voltage variation, variation in characteristics of all other devices in the equipment, equipment control adjustment, load variation, signal variation and environmental conditions. Manufacturers of valves specify three rating systems to assist the designer.

3.3.2.2 *Absolute-maximum rating system* — Absolute-maximum ratings are limiting values of operating and environmental conditions applicable to any electronic device of a specific type as defined by its published data, which should not be exceeded under the worst probable conditions.

These values are chosen by the device manufacturer to provide acceptable serviceability of the device, taking NO responsibility for equipment variations, environmental variations and the effect of changes in operating conditions due to variations in the characteristics of the device under consideration and of all other electronic devices in the equipment.

The equipment designer should ensure that initially and throughout its life no absolute-maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions and variations in the characteristics of the device under consideration and of all other electronic devices in the equipment.

3.3.2.3 *Design-maximum rating system* — Design-maximum ratings are limiting values of operating and environmental conditions applicable to a bogey electronic device of a specified type as defined by its published data, and should not be exceeded under the worst probable conditions.

These values are chosen by the device manufacturer to provide acceptable serviceability of the device, taking responsibility for the effects of changes in operating conditions due to variations in the characteristics of the electronic device under consideration.

The equipment designer should ensure that initially and throughout its life, no design-maximum value for the intended service is exceeded with a bogey device under the worst probable conditions with respect to supply volage variation, equipment component variation, variation in the characteristics of all other devices in the equipment, equipment control adjustment, load variation, signal variation and environmental conditions.

3.3.2.4 *Design-centre rating system* — Design-centre ratings are limiting values of operating and environmental conditions applicable to a bogey electronic device of a specified type as defined by its published data, and should not be exceeded under normal conditions.

These values are chosen by the device manufacturer to provide acceptable serviceability of the device in average applications taking responsibility for normal changes in operating conditions due to rated supply voltage variation, equipment control adjustment, load variation, signal variation, equipment component variation, environmental conditions and variations in the characteristics of all electronic devices in the equipment.

The equipment designer should ensure that initially no design-centre value for the intended service is exceeded with a bogey electronic device in equipment operating at the stated normal supply voltage.

3.3.3 *Atmospheric Pressure Limitations* — Ratings, in general, apply to operation at normal atmospheric pressures at altitudes below 1 000 metres and at relative humidity below 80 percent. In the event of valves being operated at other pressures the valve manufacturer should be consulted unless specific ratings are given for the intended use.

This provision refers, for example, to the use of valves in aircraft, when the reduced atmospheric pressure at high altitudes may greatly increase the risk of external voltage flashover, and may also greatly reduce the effect of convection cooling. Since many valves and other components are rated under free air conditions excessively high temperatures may be developed due to the lack of convective cooling. Particular attention should be paid to the hot spot bulb temperature of valves since, not only will the life of the valves be seriously reduced, but the characteristics may also change appreciably with the high temperature.

3.3.4 *Frequency Limitations* — When a frequency range is specified, the valve ratings apply only within this limitation. In some instances valves may be operated at reduced ratings at frequencies outside those specified for the maximum ratings. Unless, however, such reduced ratings are specified they should not be assumed without consultation with the valve manufacturer.

If some types of valves are used appreciably above their maximum frequency rating, the power dissipated in the lead-in wires owing to resistance losses and in the glass between the leads owing to dielectric losses, may be sufficient to overheat the wires or the glass. Further, there is an increased danger of damage to the valve owing to eddy current losses heating the bulb. Such effects may release gas into the valve or cause the glass to soften or crack. In the case of high-vacuum rectifiers designed for use at mains frequency, increasing the operating frequency may cause electrolysis of the glass, particularly in those types in which the anode is supported by metal *wings touching the bulb. Early failure may also occur owing to the filament resonating at the operating frequency, and either shortcircuiting to the anode or breaking due to fatigue. It is most important, therefore, that rectifiers intended for operation at 50 c/s should not be used appreciably above this frequency without the manufacturer's approval.*

3.3.5 *Pulse Operation Limitations* — Where no pulse or peak ratings are specified it shall not be assumed that the valves will function satisfactorily if the average values under pulse operation conditions are within the normal values.

Under pulse conditions, the average values of, for example, current and voltage may be well within the normal ratings but very high values will be required for short periods of time and unless the valve has been manufactured to meet these requirements premature failure may occur.

3.4 Heater or Filament Voltage Regulation and Supplies

3.4.1 *General* — A valve is designed to have optimum life and performance at its rated voltage or current and to withstand limited deviations from these values. The equipment should be so designed and adjusted that the average heater or filament voltage has the nominal rated value.

When measuring heater or filament voltages, the voltmeter should be connected to the valve pins or terminals. In addition, where the wave-form of the heater/filament supply is not sinusoidal, care should be taken to use suitable measuring instruments. Meters embodying rectifiers are generally not suitable for this purpose.

3.4.2 *Regulation of Heater or Filament Supplies* — Different conditions regarding permissible values for heater voltage or current specified by the manufacturer should be adhered to by the equipment designer.

3.4.2.1 *Abnormal voltage variations* —Should the heater or filament voltage be liable for variations larger than those indicated as permissible, and if this condition cannot be overcome in most cases, it will be necessary for reduced ratings to be applied to the valve. Information on any necessary rating changes should be obtained from the valve manufacturers in such cases.

Consistent emission from the cathode depends upon equilibrium between the evaporation of active material from the surface and its replacement from within. If the cathode temperature is excessively high, evaporation will occur at a faster rate than replacement. If the cathode temperature is too low, both evaporation and replacement will decrease. In either case the emission from the cathode will decline at an excessive rate and the life will be seriously impaired. The permissible variation of heater or filament voltage (and, therefore, of cathode temperatures) does not depend upon one *valve alone but is governed to some degree by the nature of the circuit and of the other associated valves. Active material evaporated by excessive cathode temperature may be deposited on other electrodes; if deposited on the grid it may cause grid emission thus seriously damping the input-circuit. For example, a high Mutriode which may seem quite normal on static tests may, owing to grid emission, give a poor performance under operating conditions in high impedance circuits. Deposit of active material on the surface of an insulator will reduce inter-electrode insulation and increase the risk of valve noise.*

3.4.2.2 *Parallel operation from mains* — Valves having nominal heater characteristics supplied with heater voltage in parallel from a transformer will give satisfactory operation if the voltages on the heaters and filaments are within ±5 percent of the rated value when the mains supply voltage is at its declared value. In the case of equipment designed for mains supplies between 200 and 250 volts this will require a minimum of three suitably spaced tappings on the primary of the transformer. For purpose of selecting suitable taps reference should be made to *IS : 591-1954 Specification for Low-Power, Low-Voltage Mains Transformers for Radio Receivers, Amplifiers, Small Transmitters and Similar Other Purposes.

Under these conditions, the ratings allow for the mains voltage variations not exceeding ±10 percent. Mains variations outside these limits are likely to result in some impairment of life or performance.

3.4.2.3 *Series operation from mains* — Valves designed for constant current operation shall only be used for series operation. Where valve heaters with nominal heater characteristics are connected in series with a controlling resistance, operation will be satisfactory if the heater current is within 2½ percent of the rated value when the declared supply voltage is applied and valves having nominal heater voltage drop are inserted. For equipment designed for mains supplies between 200 and 250 volts this requirement necessitates a minimum of three suitably spaced tappings on the controlling resistance.

Under these conditions, the ratings allow for mains voltage variations not exceeding ±10 percent. Mains variations outside these limits are likely to result in some impairment of life or performance. The use of certain combinations of certain types of valve heaters, owing to differing initial heating characteristics, may result in particular heaters being run at an excessive temperature during the initial warming-up period. The equipment designer should ensure that while switching on, the heater voltage of the valve does not exceed beyond the limiting values permissible for the type. To prevent this occurring, types which may be liable to damage will

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*Under revision.

AMENDMENT NO. 2 JANUARY 1975

TO

IS : 2597 (Part I)-1964 CODE OF PRACTICE FOR THE USE OF ELECTRON TUBES

PART I COMMERCIAL RECEIVING TUBES

Alteration

(*Page* 10, *clause* **3.4.2.2**, *line* 9) — Substitute ' IS : 6297 (Part II)-1973 Specification for Transformers and Inductors (Power, Audio, Pulse and Switching) for Electronic Equipment, Part II Power Transformers ' *for* ' IS : 591-1954 Specification for Low-Power, Low-Voltage Mains Transformers for Radio Receivers, Amplifiers, Small Transmitters and Similar Other Purposes '.

(ETDC 39)

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have a maximum surge-voltage rating and may require a surge-limiting device to ensure that this voltage is not exceeded. When valve heaters or filaments are connected in series from a substantially constant voltage source, or in parallel from a substantially constant-current source, or in series-parallel, the sharing of voltage or current will be determined by their resistances, which are dependent on their temperatures. These methods of interconnection cannot safely be used with combinations of directly and indirectly heated valves. When valves of different heater or filament construction are operated in such circuits, it is not sufficient to ensure that the heater or filament voltages or currents are correct in normal equilibrium operating conditions. Owing to their different temperature-resistance characteristics, it is possible that heaters or filaments may sustain abnormal temperatures during the period between switching-on and the establishment of equilibrium, and also when changes occur in the supply voltages.

In AC/DC equipment it is not good practice for the series resistance employed in the mains supply to be common to both HT and LT supplies for the following reasons:

a) Automatic gain control (AGC) will vary the total value of HT current, and this current passing through the common resistance will affect the valve heater voltage, thus causing greater variations than would be experienced owing to mains variation only.

b) Variations in HT load current due to tolerances on valves and components will cause an additional variation in heater current.

c) The total RMS current taken by the equipment with AC operation will be greater than the total DC current with DC operation. A set correctly adjusted for the latter would, therefore, underrun the heaters on an AC supply.

3.4.2.4 *Parallel operation from lead-acid or nickel-iron cells* — Valves designed and recommended for use with chargers are intended to give satisfactory performance over the range of battery supply voltage expected with and without a charger.

a) *Lead-acid cells* — The overall variation is from 1·8 to 2·5 V per cell although it is appreciated that infrequent short-term fluctuations may raise the voltage to 2·7 V.

b) *Nickel-iron cells* — The mean voltage per cell should be taken as 1·25 V without charger and 1·4 V per cell with charger.

3.4.2.5 *Other sources of supply* — Where supplies for valves are derived from sources other than those considered in the above clauses, the controls should ensure that the filament/heater voltages are within ±7½ percent of the rated values.

3.4.2.6 *Operation of heater or filament supplies above 50 c/s* — It should not be assumed that heaters designed for 50 c/s will operate satisfactorily at higher frequencies. The valve manufacturer may be consulted for operation at higher frequencies.

3.5 Mounting

3.5.1 Valves are mounted in equipment by a number of methods. In many cases they are inserted into plug-in holders which provide mechanical support and electrical connections. Components used in making connections to valve terminals should be chosen with care to avoid the development of bad contacts.

This precaution is specially important when spring loaded connections are used, for example, in valve-holders for push-in mounting, since the heat developed at a poor contact tends to damage the springs and leads to progressive deterioration. Such a defect in the cathode-heater circuits will reduce cathode temperature with resultant impaired performance, and, in many cases, in reduced life. In the grid circuit a bad contact could introduce noise, or in an extreme case cause rapid failure of the valve by removing or reducing the grid bias.

3.5.2 *Vertical Mounting* — It is generally desirable that valves should be mounted base downwards and in a vertical position. Many modern valves are designed for, and may be used in, other positions, but when the manufacturer's published literature does not give any guidance, the manufacturer should be consulted before any change from the vertical method of mounting is adopted.

Mounting valves with the base upwards will affect the flow of air around the bulb and may result in the limiting temperature of the bulb or the holder be exceeded. If that part of the bulb on which the getter is deposited becomes overheated, gas will be released and the valve will become ' soft '. If the pinch of some valves is overheated the inter-electrode capacitance will change, and when valves are used as oscillators, frequency drift will result. In other cases overheating of the pinch may give rise to electrolysis of the glass, resulting in breakdown. If the base is overheated the cement may contract and the base become detached from the bulb.

3.5.3 *Horizontal Mounting* — Where it is necessary to mount valves horizontally, the plane of the filament of directly heated valves should be vertical. Similarly for certain indirectly heated valves having a high mutual conductance, the plane of the major axis of the control grid should be vertical.

A particular instance where this precaution is necessary is that of battery type valves where manufacturers use the minimum number of hooks for supporting filaments to obtain optimum characteristics. They also use very small clearances of the order of a few thousands of an inch for valves of high mutual conductance. When such valves are mounted otherwise than in the upright position, they may be more microphonic or the relative movement *of the electrodes may change the characteristics of the valve, or even cause failure due to contact between electrodes. The adoption of the recommendations given above reduces these risks.*

3.5.4 *Mounting of Small Glass-Based Valves Including Miniature and Sub-miniature Valves* — Many of these glass-based valves employ semi-rigid pins and unless these are provided with a pin protector, it is advisable that the pins should be straightened in a pin straightening tool before insertion into the socket.

It is recommended that for holders with floating contacts a wiring jig be used to ensure that the holder contacts are in correct position to receive a valve after the holder has been wired. The connections to those floating contacts should be as flexible as possible. The use of too stiff wiring will destroy all the advantages provided by the float of the contacts and may hold the contacts so far out of position as to result in damage to the valve bases.

It is also recommended that one of the withdrawal tools designed for the purpose should be used to remove the valve from the valve-holder to minimize damage to the glass base.

3.5.5 *Mounting of Miniature and Sub-miniature Valves Having Flexible Leads* — It is usually necessary to secure the valves of these types in position by the envelope. Care should be taken to see that the safe bulb temperature as specified by the manufacturer is not exceeded owing to the method of mounting used. Excess bulb temperature rise may often be avoided by the use of mounting clamps of high thermal capacity and conductivity placed in intimate thermal contact with the envelope. In addition, all mounting clamps should have a blackened inner surface so that heat is not reflected back into the valve.

Nearly half the cooling of a bulb in free air is due to convection, but in a well-designed metallic mounting clamp more than half the heat can be removed by conduction. Metals of high conductivity should be used and contact with the envelope should be over as large an area as possible. Efficient cooling is obtained only when the mounting clamp makes good thermal contact with the bulb and with cooler metal in the equipment.

3.5.6 *Glass-to-Metal Seals* — Connections having sufficient flexibility to allow for mechanical tolerances and also for thermal expansion and other movements should be employed where strains might be set up in glass-to-metal seals. These connections should be designed to avoid losses arising from poor contact and to facilitate adequate heat conduction and radiation.

3.5.7 *Spare Socket-Contacts* — It is recommended not to utilize the tags of spare valve-holder contacts as anchoring pins for circuit wiring.

Difficulties may arise if a valve is replaced by another having different internal connections to the pins.

This practice may adversely affect the characteristics of valves with glass bases by the application of potentials to pins which are not connected to any valve element but which project into the envelope.

3.5.8 *Internally Connected (IC) Contacts* — When a pin in the list of connections is marked 'internally connected' (IC) it is particularly important that no connection be made to the corresponding valve-holder tag because the pin may be supporting or inter-connecting an electrode inside the valve. Such internal connections may differ for valves of a given type made by different manufacturers; over a period of time they may differ during the production of a valve by one manufacturer.

3.5.9 *Soldering of Rigid or Semi-rigid Pins* — It is highly undesirable to solder connections directly to rigid or semi-rigid pins in glass bases or to such leads sealed through the envelope. The application of heat introduces strain in the glass, the effect of which may not be immediately apparent, but it may subsequently impair the vacuum or crack the seal.

3.5.10 *Soldering of Flexible Leads* — Care shall be taken to avoid bending the leads sharply close to the glass, for valves designed for soldering the leads into the circuit. Care shall also be taken to avoid overheating the glass-to-metal seal by heat conduction along the lead. It is recommended to use a thermal shunt of adequate heat capacity between the point of soldering and the glass seal. In any case the wire should not be soldered closer than 5 mm from the seals of miniature and sub-miniature types, or as specified by the manufacturer. A pair of pliers or clip with 'copper' jaws of a minimum of 3 mm width attached, can be conveniently used as a thermal shunt for wiring miniature and sub-miniature valves. Besides protecting the seal from thermal shock it ensures that the joint cannot be made nearer the seal than the specified minimum distance. Where conditions preclude the use of a thermal shunt particular care should be taken that the temperature of the soldering iron is kept high and its application limited to the minimum time.

3.5.11 *Effects of Stray Fields* — The operation of valves may be seriously affected by magnetic or electro-static fields, hence they should be positioned and/or shielded so that the deleterious effects of such fields are reduced to a minimum.

The electron stream can be deflected or modulated by the stray fields from transformers, loudspeaker magnets, high-potential components and wiring, thus adversely affecting the operation of the controlling electrodes. Low voltage battery valves are particularly susceptible to such defects.

3.5.12 *Insulation Resistance of Valve Mounting* — Where a valve is followed by a high gain amplifier, the insulation of the valve socket and leads shall be adequate, in relation to the magnitude of currents and voltages, to avoid the introduction of harmful effects due to leakage currents. In the case of certain valves where the input impedance is high, the introduction of minute currents or voltages due to inadequate insulation will produce serious effects in normal operating conditions, for example, inadequate insulation in the mounting or leads of a photocell will produce random fluctuations in output; similarly, low insulation between grid and heater in a low-noise valve will cause excessive hum.

3.6 Ventilation

3.6.1 *Layout of Equipment*

3.6.1.1 The layout and design of equipment should afford sufficient ventilation to ensure a safe bulb temperature under all conditions. As a general guide, the maximum temperature of the hottest part of the bulb under operating conditions in the equipment should not exceed by more than 20 centigrade degrees that temperature which would be obtained if the valves were operated at its maximum rating under conditions of free air circulation in a room temperature of 20°C.

3.6.1.2 Exceptional increases of temperature may arise where valves are used in screening cans and in equipments working at high ambient temperature conditions. Screening cans should only be used where necessary and they should always have black inner surfaces to prevent the reflection of heat back into the valves. Screening cans with bright inner surface should never be used.

3.6.1.3 Small glass based valves, including miniature and subminiature valves with flexible leads, should be operated in free air conditions where good air circulation is possible and preferably in some form of heat-conducting shield. Where air ventilation is likely to be inadequate, heat conduction shields should always be used or the valves should be derated so that the bulb temperatures are maintained at safe levels. Material reductions in maximum bulb temperature can be achieved by the use of conduction cooling by screening cans specially designed to make close contact over a large area with the bulb. The valve manufacturer should be consulted regarding each valve type concerned.

The present trend in valve design is to reduce dimensions with the object of saving space and of improving efficiency at high frequencies, and the extent to which reduction can be made is usually limited by the amount of heat which can be dissipated from the exterior surface of the bulb. As the proportion of heat dissipated from a valve by radiation is of the order of 50 percent, it is necessary to allow adequate conditions for free radiation from the surface of the bulb to cooler surroundings.

The increase in the temperature of air in convective cooling is very small and it is, therefore, more important that the flow of air should be copious and unimpeded than that it should be particularly cold. No great risk is incurred if the air is slightly warmed by passing near other components if this allows it to flow through a less obstructed path, but valves should not be positioned adjacent to components running at very high temperatures such as mains resistors, where direct radiation could seriously affect the bulb temperature. To improve radiation from the valve, surrounding surfaces should not be polished and should be kept as cool as possible.

3.6.2 *Mounting Position* — When valves are mounted in other than upright positions, greater care is necessary to ensure adequate ventilation so that the maximum rated temperatures are not exceeded.

3.6.3 *Free-Air Cooling* — Adequate ventilation is of special importance for power-amplifier valves and rectifiers.

3.6.3.1 When valves designed for free-air cooling are used in conditions where free convection cannot be maintained, steps should be taken either by reduction in dissipation or by forced air cooling to ensure that limiting bulb temperature is not exceeded. The cooling air stream should be directed to flow evenly over the surface of the bulb.

3.6.4 *High Voltages* — Particular care should be taken to maintain adequate ventilation where high voltages are concerned, to avoid insulation breakdown due to ionization or tracking.

3.6.5 *Dust Precipitation* — The precipitation of dust is considerably increased at high voltage and in the vicinity of high voltage connections. This may result in insulation breakdown or variable leakage resistance and thus may affect operation of the equipment. Inadequate cleaning may increase the danger of breakdown by producing high voltage-gradients.

3.7 Heater-Cathode Insulation

3.7.0 *General* — It is recommended to keep the potential between heater and cathode as small as possible. Under no circumstances the maximum value should be exceeded which will result in danger of breakdown between heater and cathode.

3.7.1 *AC or DC Voltages* — The voltage between cathode and heater may be DC or AC or a combination of both voltages. When AC voltage is used adequate precaution should be taken to ensure that the peak value of the voltage is well within the limiting values. Manufacturer should be consulted for safe values of these voltages. Frequently, the ratings for the cathode positive to heater and those for the cathode negative to heater are widely different and such ratings should be carefully observed. Maximum ratings are normally specified in published data, but when not published, details should be obtained from the valve manufacturer. When the heater is positive with respect to cathode sleeve, there may be a breakdown caused by the electrolysis of the insulating coating.

The materials, dimensions and method of applying the heater-cathode insulation are selected to give the most satisfactory compromise between the conflicting requirements of good electrical insulation and high thermal conductivity and in order to produce the modern quick-heating valve some increase in electrical conductivity has been inevitable. Even with quite low heater-cathode voltage some current may flow, while with increasing voltage the current increases (not necessarily in proportion to the applied voltage) until the insulation breaks down. When the cathode is positive to the heater there may be some current due to emission from the heater in addition to the leakage current across the insulation.

3.7.2 *AF or RF Voltages* — The insulation resistance between the heater and the cathodes should not be included in RF circuits where frequency stability or preservation of wave form is important, or in AF circuits followed by high gain.

The leakage currents make themselves apparent as noise or hum which may assume serious proportions if the valve in which they originate is followed by a large degree of amplification. Moreover, if the heater-cathode insulation is included in a tuned circuit, any alteration to the physical or electrical properties of the insulation will alter the frequency to which the circuit is tuned, and if both RF and AF (for example, mains frequency) voltages exist across the insulation, there is a risk of modulation hum, particularly in cathode-coupled oscillators and the like. There is also some risk of the introduction of hum and noise due to spurious emission from the cathode as a result of the heater-cathode potential difference.

3.7.3 *Cathode Keying* — The practice of 'keying' by opening a cathode circuit may result in a large potential difference between heater and cathode and should be avoided. If cathode 'keying' is essential a resistance not exceeding 0·25 megohm should be connected between heater and cathode.

Similar precautions should be taken for those valves in a radio receiver or radiogram, the cathode circuits of which may be opened to mute them while gramophone records are being played. The suggested value of 0·25 megohm for the resistance is approximate only and the actual value should be determined for each circuit.

3.7.4 *Isolated Heater Windings* — When a valve is operated from a separate transformer winding, it is essential that a DC connection should exist between this winding and the cathode to avoid heater-cathode insulation breakdown. Where this connection does not exist a resistor of the order of 100 000 ohms should be connected between heater and cathode.

The heater will develop a potential relative to the cathode depending on the ratio of the heater-cathode insulation resistance to the insulation resistance between the heater winding and other windings, and on the voltages involved.

3.8 DC Connections Between the Cathode and Other Electrodes

3.8.1 In no circumstances should valves be operated without a DC connection between each electrode and the cathode. If the connection includes a component such as a rectifier having a resistance dependent upon the polarity or magnitude of the voltage applied to it, care should be taken to ensure that the electrode can never attain a potential uncontrolled with respect to the associated cathode.

3.8.2 The total effective resistance between any electrode and the cathode should be the minimum practicable. It is important to remember that any apparent advantage of an (open-circuited) electrode or of a high-resistance path may be lost because of secondary emission characteristics of the valve.

3.9 Control Characteristics with Directly-Heated Cathode — The grid and anode potentials on which the published control characteristics are based are given with reference to the mid-point of the cathode (which may be simulated by the mid-point of the cathode heater transformer winding, or by an artificial mid-point). If circuit connections are made to one end of the filamentary cathode, allowance should be made for the cathode voltage in interpreting the characteristics.

3.10 Control-Grid Voltages and Currents

3.10.1 *General* — It is recommended that the resistance between the control-grid and cathode should be kept as low as possible. Published data usually include limiting values, but where these are not given the manufacturer should be consulted.

In most circuits, including all Class A applications, only negligible currents flow in the control-grid circuit, therefore, the impedance of this circuit can be made quite high without producing any serious reduction of the grid input compared with its value on open circuit. The necessity for setting an upper limit for the permissible grid-circuit resistance arises from other conditions, the most important being as follows:

a) *Gas current — This current is due to the collection by the grid of positive charged ions produced by collisions between electrons and any gas molecules present in the valve. Although normally this 'gas-current' is of the order of a fraction of a microampere only,* *it may amount to many times this value, possibly owing to overheating, if the valve contains much gas.*

b) *Grid emission — This arises if the grid has collected active materials evaporated from the cathode during manufacture or while in service, and when the temperature of the grid is raised by operating conditions.*

c) *Leakage current — Due to the high temperature and short paths employed on many valves, leakage current across the insulation between the grid and other electrodes is liable to result from the deposit of volatilized metallic materials.*

3.10.1.1 All these effects are equivalent to a resistive-shunt across the input circuit, and result in a reduction of the grid-input voltage; they may also reduce the selectivity of the preceding tuned circuit and alter the DC value of the grid current potential, the change in the effective grid bias generally producing an increase in anode current and, if the grid current is due to a cause arising from over-heating, the increased anode current will make the valve still hotter and the effect will be cumulative until a state of equilibrium is reached. In RF valves the state of equilibrium is usually a condition in which the grid is very positive, and the gain very low. In output valves equilibrium may not be reached until the anode current is so high as to destroy the valve or some other component.

3.10.2 *Positive Grid Current* — Valves should not be used in applications, which may result in appreciable grid current, such as in Class AB2, B and C amplifiers, without the approval of the manufacturer, unless such use is indicated in the manufacturer's published information.

3.10.3 *Derivation of Grid Bias* — It is most undesirable that valve bias should be provided solely by grid rectification, except when suitable precautions have been taken to prevent damage to the valve from loss of drive.

In many valves the cathode current at zero bias is sufficiently large to cause excessive anode dissipation. When operating bias is obtained solely by grid rectification or series grid resistance, this bias will disappear on the cessation of grid current because of failure of oscillation or driving voltage. Unless precautions are taken to switch off or to reduce electrode voltages in the event of such failure, the resulting excessive heating may damage or destroy the valve. It is recommended, in the absence of suitable precautions to prevent this, that a proportion of the required grid bias be derived either from a fixed voltage supply or by auto-bias. This proportion should be sufficient, in the absence of grid current, to reduce the anode current to a value below that corresponding to the maximum rated anode dissipation.

3.11 Screen-Grid Voltages : Source of Supply Voltage

3.11.1 When a voltage divider is used to supply voltages on screen-grids of multi-electrode valves, the resistance employed should be as low as practicable. Unaligned tetrodes and aligned grid valves operating with a voltage on the screen substantially lower than that on the anode should derive their screen voltage from a potentiometer network or a voltage source having good regulation. The screen voltage of unaligned pentode valves may be derived by means of a series resistance. In the case of frequency changers, reference should be made to the published data or, if necessary, to the manufacturers. If the screen-grid voltage is allowed to exceed the anode voltage, care is necessary to ensure that the screen-grid dissipation is not exceeded. Particular care should be taken to avoid removing the anode voltage whilst the screen-grid is energized.

The screen current of aligned grid valves and unaligned tetrodes is subject to wider variation, both in manufacture and under operating conditions, than that of unaligned pentodes. Hence considerable variations in screen potential may arise between different equipments or with different valves in the same equipments if the control of this potential is solely due to the valve screen current.

Certain output valves when run near the maximum screen dissipation can generate appreciable screen emission and if operated so that during part of the cycle the anode is highly positive with respect to the screen, a high resistance in the screen supply may cause sufficient change in the operating conditions to endanger the valve or associated components.

3.12 Suppressor-Grid Voltages

3.12.1 *Negative Voltages* — The suppressor-grid of a multi-electrode valve should generally be maintained at the same potential as the cathode. In certain applications it is permissible to connect the suppressor-grid to the negative and of the cathode biasing resistor or to the AGC line instead of directly to the cathode.

3.12.2 Valves should not be operated with a negative potential on the suppressor-grid sufficiently great to cause the screen-grid dissipation to exceed its safe value. Unless the manufacturer's published data include suppressor-grid characteristics, or other indication of the performance of the suppressor-grid is given, it is unwise to design equipment in which reliance is placed on uniformity of this parameter.

3.12.3 *Positive Voltages* — Valves should not be used in circuits or applications which result in appreciable suppressor-grid current. It is, therefore, important that in the case of pentodes connected as triodes, the suppressor-grid should normally be connected to the cathode rather than to the anode. Certain valves have low-current diodes internally connected to the suppressor-grids which are intended to act as DC restorers and thus prevent the suppressor-grid from being driven appreciably positive. Positive voltages may be applied to the suppressor-grids of valves designed for transmitting or for suppressor-grid modulation only where this type of operation is indicated in the published data.

3.12.4 *Limiting Circuit-Resistance* — Resistance in series with the suppressor-grid should be avoided. Where resistance is essential it is recommended that the valve manufacturer should be consulted as to its value. Where a valve is specifically intended for suppressor-grid modulation such information will normally be published.

3.13 Microphony

3.13.0 To reduce microphony, valves should be mounted so that they are as free as possible from mechanical or acoustic vibration.

3.13.1 External factors which determine the extent of microphonic effects include:

a) The amount of amplification following the valve;
b) The method of mounting the valve;
c) The position of the valve in relation to any source of vibration;
d) The intensity of the vibration reaching the valve;
e) The frequency characteristics of the whole system; and
f) The amplitude of the carrier frequency, where the microphonic valve is in an RF circuit.

3.13.2 The following recommendations, if carried out, will greatly assist in reducing microphony to a minimum:

a) Wherever practicable the source of vibration should be resiliently mounted.
b) The chassis containing the valves should be mounted on resilient bushes.
c) Those valves which are followed by the largest degree of amplification can, with advantage, be mounted in antimicrophonic valve-holders, or in holders which are secured to the chassis through rubber grommets, care being taken that the leads to the valve-holders and also the top caps, if any, of the valves are as flexible as possible.
d) Valves, particularly those valves which are most susceptible to microphony, should not be mounted immediately behind or close to a loudspeaker. It is also an advantage if the valves

can be shielded to some extent from any direct sound waves by the interposition of other components.

Microphony in a valve consists of rhythmic variations in the output of the valve caused by small variations of electrode spacing (either inter-electrode or between any electrode and an external object) due to mechanical vibrations transmitted to the valves from some external source.

Such vibrations, which may or may not originate in the signals passing through the valve, may reach the valve either as direct vibrations of the chassis transmitted through the valve-holder to the valve pins and thus causing the valve to vibrate as a whole, or as sound waves impinging on the envelope and conveyed through the mica supports, etc, to the electrode structure.

If the valve is being used in an audio-frequency circuit, vibrations of the electrode structure may produce interference signals even when the valve is handling no ' wanted ' signals. If, on the other hand, the valve is operating in a high-frequency (RF or IF) circuit, microphony vibrations will create interference only if a high-frequency carrier is present. In these circumstances the microphony vibrations will modulate the carrier and will become evident after the detector stage.

3.14 Special Considerations Stand by Operation

3.14.1 *Cathode Current* — Certain types of valves should not be run for long periods with cathodes heated and without cathode emission current flowing. Where such conditions are necessary, the valve manufacturer should be consulted.

Operation of a valve for longer periods with cathodes heated but without cathode current being drawn may result in a resistive layer between the metallic cathode and its emissive coating. This resistance appears in the cathode circuit. This would result in negative feed back and degrades the performance of the tube due to the apparent reduction of mutual conductance.

In the absence of cathode emission current, the cathode is liable to become poisoned and the resulting loss of emission may prevent the valve from operating satisfactorily when required.

3.14.2 *Electrode Dissipation* — The life of a valve is partly dependent upon the heat dissipated by its various electrodes and all possible precautions should be taken to ensure that this is kept at minimum. Excessive dissipation may be caused by incorrect tuning of associated circuits, unnecessarily high no-signal current, parasitic oscillations, etc.

Excessive dissipation may result in the evolution of gases and/or generation of emission from the electrodes, with consequent disturbances of the operating conditions.

3.14.3 *Contact Potential* — Circuits which employ valves under conditions requiring a close control of contact potential (voltage corresponding to a start of positive current to any electrode) should be avoided unless the published valve data indicates that this characteristic has been adequately specified.

Most valves undergo a process of ageing during life which is more pronounced during the early stages. The surfaces of the cathode and of the control grid undergo certain changes which may result in progressive variation in the contact potential. It is usually possible to reduce such variations to a minimum by special processing of the valve during manufacture, but such steps are often costly and are not economically justified except for special valves designed for particular applications.

3.14.4 *Cross-Coupling in Multiple-Unit Valves* — Electrons emitted by one cathode of a multiple-unit valve may reach the electrode of other units within the same envelope and cause undesirable coupling between otherwise independent units and their associated circuits.

Cross-coupling may also arise as one of the effects of bulb charge, that is, when a stream of electrons originating from the cathode of one unit strikes the glass envelope which thereby acquires a negative charge over the area under bombardment. Such a charge, which may be varied by the electrode potentials of the originating unit, can also modulate the electron stream of other units within the envelope.

Both of the above effects can give rise to a condition whereby it becomes impossible to cut off one or more units completely regardless of the magnitude of the applied grid voltage. Equipment designers using multiple-unit valves in circuits where the effects of cross-coupling are important should ensure that the valve is suitable for such applications. Otherwise, the circuits should be designed to be tolerant of cross-coupling. Multiple-unit valves having internal electrostatic shielding are less susceptible to the effects described.

3.15 Damage to Equipment — Some valves, particularly rectifiers, may ultimately fail by arcing or short circuiting. with serious consequences to other components. Therefore, it is essential for a fuse or other protective device of suitable rating to be provided.

3.16 Storage and Transit

3.16.1 Valves not installed in the equipment should be stored in their original packing or in suitable racks.

3.16.2 Normal good storage conditions should be provided to prevent deterioration, such as corrosion of contacts or impairment of electrical insulation.

3.16.3 Valves should always be transported in the original packing designed for the purpose.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Conversion*
Force	newton	N	1 N = 1 kg.1 m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

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